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Short Synopsis

Performance and Exhaust Analysis of Methanol - Gasoline Blends in Single Cylinder Four Stroke Spark Ignition Engine

Ph.D. Programme

DEPARTMENT OF AUTOMOBILE ENGINEERING

FACULTY OF ENGINEERING & TECHNOLOGY

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Declaration

This is to declare that this short synopsis reflects the research work design and its contents are the original piece of work, as per guidelines, grammatically correct and free from plagiarism. This has been prepared under the guidance and supervision of my supervisor.

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Certificate

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Recommendation

I recommend this short synopsis prepared and submitted by Mr. Naveen Kumar for approval of Ph.D. Doctoral Research Board and thereafter to be uploaded on Shodh Gangotri.

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ABSTRACT

Methanol is the simplest form of alcohol having single carbon solution as it has no carbon carbon bond, so it does not emit particulate matter making the fuel clean. Methanol is a toxic, colorless, tasteless liquid with a very faint odour treated like petrol. Though it is presently being made from natural gas, it can also be produced from a range of renewable sources such as agricultural waste, forest residue and naphtha and wood, coal and biomass through gasification. With methanol blends up to 15 percent the existing engine with minor modification can be made compatible. For more or neat methanol the engine needs alteration. The high octane ratings and greater heat of evaporation values of methanol make them suitable fuels for high compression ratios engines with high powers. Methanol's advantages include lower emissions, higher performance and lower risk of flammability than petrol. The auto-ignition temperature of methanol is higher than those of gasoline, which make it safer for transportation and storage. Also the heat of evaporation of methanol is 3 to5 times higher than that of gasoline, this makes the temperature of the intake manifold lower, and increases the volumetric efficiency. With the above benefits associated with methanol blends present study investigates its performance on the single cylinder petrol engine. The study also tries to get complete knowhow about the emissions with the changes in the blends ratio. Also the effects of the blends on the engine hardware material behavior will be investigated. Tail pipe emission reduction is another area where the study will be made for making blended fuel system compliance with the Bharat stage (BS) norms.

Key words: Engine, Methanol, Emission, Bharat Stage Norms, Gasoline, Retrofit system, Tailpipe.

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INTRODUCTION

The world is presently facing two problems one is fossil fuel depletion and another is damage of the environment by the harmful emissions, with the extensive use of internal combustion engines. Due to high rate of fossil fuel extraction and its uncontrolled utilization have led to reduction in underground-based fossil fuel resources. Energy source which can make pleasant alliance with the environment, with sustainable development, energy conservation, efficiency and environmental protection is the point of today's research. Energy demand of India is expected to rise at a compounded annual growth rate (CAGR) of 3.5% till 2040 as reported by (Saraswat & Bansal 2006). India has increased its primary energy demand by import of crude oil and natural gas from 73% and 17% in 2005-06 to 81% and 40% in 2015-16 respectively. But, there has been a bleak growth in domestic oil (CAGR – 1.4%) and natural gas (0.01%) production over the last decade (Saraswat & Bansal 2006). The growth rate of consumption of oil in India year on year is shown in Figure 1.

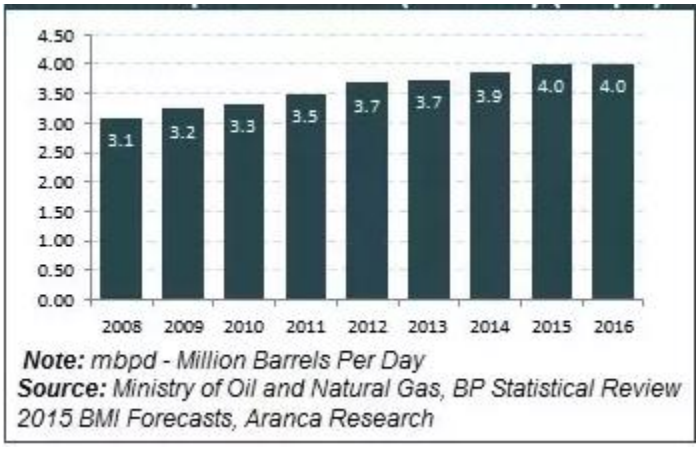

Figure 1. Oil Consumption in India (2008-16). (Quora 2015)

Diesel constitutes 40% of total fuel consumption in India while gasoline consumption is 12%. Gasoline has the highest average growth rate among oils which is 15.56% during March 2016. So moving by this trend the consumption of petrol today is about 14%. 14 % of 4.1 million barrels per day (mbpd) is 0.574 mbpd which would be 574000 Barrels per day and in terms of liters its will be 91258707.29 liters per day.

Alternative fuel, alcohol acts a good substitute for S.I engine. It has properties with are similar to gasoline fuel. Also octane rating of alcohol is above 100. No modifications in the engine are required if small amount of alcohols are added in gasoline. Among the alcohols,

methanol has the lowest combustion energy. However, it also has the lowest chemically correct air-fuel ratio. Therefore, an engine burning methanol would produce the maximum power as reported by (Sayin 2010)

As per data supplied by SIAM (Society of Indian Automobile Manufactures 2017) Table 1. The total sales of two wheelers is 1,75,89,511 units in 2017 which is about 80.5% of the total sales of vehicles. The percentage wise sales of passenger vehicles, commercial vehicles, three wheeler, and two wheeler is 13.93%, 3.26%, 2.34% and 80.5% respectively for 2017. The data shows that two wheeler segment have the large contribution of total vehicle sales in 2017.

Table 1. The Automobile Domestic Sales growth year on year (SIAM 2017).

Vehicle Type	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
Passenger vehicles	26,29,840	26,65,016	25,03,510	26,01,237	27,89,209	30,46,728
Commercial vehicles	8,09,500	7,93,212	6,32,852	6,14,949	6,85,705	7,14,233
Three wheelers	5,13,282	5,38,291	4,80,086	5,32,627	5,38,209	5,11,659
Two wheelers	1,34,09,151	1,37,97,186	1,48,06,779	1,59,75,562	1,64,55,852	1,75,89,512
Grand total	1,73,61,770	1,77,93,702	1,84,23,224	1,97,24,372	2,04,68,972	2,18,62,129

As per Petroleum Planning & analysis cell (PPAC) Report two wheeler segment accounts for highest consumption of petrol i.e. 61.42%, as compared to cars which is at 34%, and three wheelers at 2.34%. (PPAC 2018) The same is shown with the help of the Figure 2.

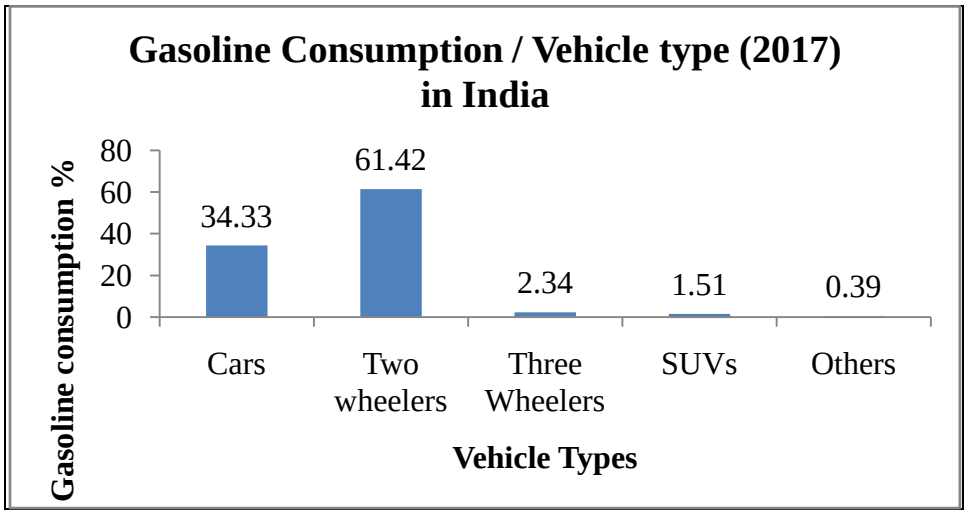

Figure 2. All India End-use shares (%) of Petrol in Retail (PPAC Report)

The undesirable emissions produced during combustion of fossils fuels in internal combustion engines. The emissions like un-burnt hydrocarbons (HC), oxides of carbon (COx), oxides of nitrogen (NOx) oxides of sulphur (SOx), and solid carbon particulates which pollute the atmosphere and causes various problem like global warming, acid rain, smog and respiratory and other health hazards. From the point of view of pollution control, measurement of

emissions from engines is very important issue. Bharat stage (BS) emission standards are notified by Government of India to control the air pollutants emitted by IC Engines. Their reference source and the date of application in India are shown in Table: 2

Table: 2 Indian Emission standards for two wheelers. (BSES 2017)

Standard	**Reference**	**Date**
Bharat Stage II	Euro 2	1 April 2005
Bharat Stage III	Euro 3	1 April 2010
Bharat Stage 1V	Euro 4	1 April 2017
Bharat Stage V1	Euro 6	April 2020 (proposed)

The decline in the emissions of CO & HC+NO_x for the case of two wheelers is shown in the Figure 3.

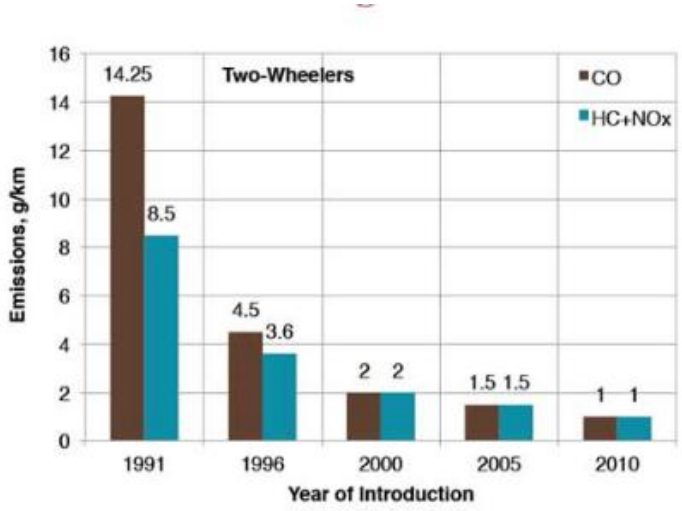

Figure 3 Decline in the emission for two wheelers (SIAM 2017)

The vehicle having BS-IV engine is overall better than BS-III in terms of emissions. The difference between BS III and BS1V in terms of emissions is that in case of BS III carbon monoxide (CO) emission are at 2.30 g/km. Hydro Carbon (HC) 0.20 g/km & Nitrogen Oxide (NO_x) 0.15 g/km whereas in BS1V CO emission are reduced to 1.00 g/km, HC to 0.10 g/km and NO_x to 0.08g/km the same is shown in the Table 3:

Table 3: Emission standards for two wheel petrol vehicles g/Km (Vashist et al. 2017)

Norms	CO	HC	HC + NOx
1991	12 to 30	8 to 12	-
1996	5.5	-	3.6
BS-1 (2000)	2	-	2
BS –II (2005)	1.5	-	1.5
BS III (2010.04)	1	-	1

The following changes have been made for BS III TO BS IV compliance two wheelers system

1. Emissions levels of Carbon Monoxide and Hydrocarbon + Nitrous Oxide (HC + NOx) reduced from 1.00 g/km to 0.75g/km.
2. The octane number for petrol (91) and cetane number (51) for diesel are same in BS III and BS IV but sulphur content has been reduced. For petrol it is reduced from 150 mg/kg to 50 mg/kg and for diesel it is reduced from 350 mg/kg to 50 mg/kg.
3. The emission content is reduced by the use of carbon canisters which absorbs the harmful vapors and gases emitted by the vehicle.
4. Regulations restrict evaporation emissions control system is installed in the BS IV vehicles where in on the fuel tank a new breather value with a changed design is fitted along with additional brackets that hold these new systems.
5. Auto headlamp on (AHO) for reducing crashes in two wheeler is another feature for BS IV norms compliance vehicle.
6. BS IV engines at tail pipe, oxidation of NO_x is made with the help of secondary airflow system that adds oxygen (or natural air) to the exhaust stream just before the catalytic converters.
7. Many manufacturers are adapting to the ECU (Electronic control unit) and ignition control setup which helps in clean burns and reduced emissions.

Methanol as an alternative fuel

Methanol is a very versatile chemical primarily produced in India from natural gas and naphtha. Current methanol consumption is 1.5 million tonnes. The demand is growing at 11% and import is one of the options to fulfill this demand. (Saraswat & Bansal 2006) Chemical and energy are the two major end-use segments for methanol. Formaldehyde, acetic acid, di-methyl terephthalate (DMT) and a variety of solvents are the main items produced from methanol in the chemical segment. Methanol is heavily used as a blending component for petrol and methyl

tertiary butyl ether (MTBE), tertiary amyl methyl ether (TAME) and di-methyl ether (DME) in the energy segment (Saraswat & Bansal 2006).

Worldwide status of methanol:

There are more than 90 methanol plants in world, having a joint production capacity of about 110 million metric tons (almost 36.6 billion gallons or 138 billion liters).According to IHS (information handling services), worldwide methanol demands reached 70 million metric tons in 2015. (SIAM 2017)

Table 4: Annual production of methanol (Saraswat & Bansal 2006) (Malvarado 2016)

Segment	Annual Production
World	70 million tonnes
Asia	44 million tonnes
Middle East	9 million tonnes
US	2 million tonnes
India	0.163 Million tonnes

Methanol as a fuel for in Indian Economy:

Methanol can play an important role to control the increasing imports and recover the energy security of India. The Government is likely to go ahead with a objective of 15% blending by methanol in gasoline / diesel by 2022 which if attained could result in savings of around $8 billion (based on the 2016-17 price of India basket of crude oil, which is likely to rise in the medium and long term) by 2022 (Saraswat & Bansal 2006)

In recent times, Coal India Limited (CIL) has exposed its plan to set up a coal based methanol plant in West Bengal and has even invited bids from licensors of coal gasification technology to set up a coal to methanol plant which is a step in the right direction. Therefore, India can and must leapfrog to a Methanol Economy which could significantly reduce its import dependence and carbon footprint (Saraswat & Bansal 2006).

India is at a rising stage in methanol production and usage. There are five main producers of methanol in India – Gujarat Narmada Valley Fertilizer & Chemicals limited, Deepak Fertilizers, Rashtriya Chemicals and Fertilizers, Assam Petrochemicals and National Fertilizers Limited. The following figures would give an overview of the methanol industry in India.

Table 5. Overview of the methanol industry in India (PPAC 2018)

Year	Capacity (MT)	Domestic production (MT)	Capacity Utilization (%)	Consumption (MT)
2010-11	0.496	0.375	76%	1.14
2011-12	0.496	0.360	73%	1.44
2012-13	0.474	0.255	54%	1.47
2013-14	0.474	0.307	65%	1.54
2014-15	0.474	0.210	44%	1.80
2015-16	0.474	0.163	34%	1.83

Table 5 suggest that the domestic production of methanol has decreased by 57% from 2010-11 to 2015-16, whereas the consumption has increased by 61% over the same period. Since falling domestic production has led to constant decline in the capacity utilization of Methanol Industry.

Table 6: Methanol Import / Export status for India (PPAC 2018)

Year	Imports(MT)	Exports(MT)	Net Imports
2010-11	0.81	0.044	0.77
2011-12	1.20	0.120	1.08
2012-13	1.40	0.185	1.21
2013-14	1.31	0.082	1.23
2014-15	1.64	0.049	1.59
2015-16	1.71	0.044	1.67

Table 6 shows that imports of methanol has been increased more than doubled from 2010-11 to 2015-16.Inspite of having unutilized capacity India fulfill their 90% requirement through importing of methanol because it is cheaper for India in comparison with domestic production. India imports 99% of its methanol from Iran (1.31 MT) and Saudi Arabia (0.38 MT), where natural gas is abundantly available at low cost.

Methanol production: An opportunity for India

In India methanol is produced from imported natural gas. It is expected that if coal is used for the production of methanol it will provide methanol economically as compared to natural gas.

It is estimated that a 1600 tons per day of methanol plant will require a capital expenditure of approximate INR 1200 Cr which would be able to produce methanol at INR 17- 19 per liter which is comparable with the cost of imported methanol. Whereas, presently, per liter cost of methanol production in India is INR 25-27 or even more depending on the the price of imported natural gas. Apart from using coal as a feedstock, biomass/municipal solid waste and flared natural gas can also be used for methanol production, but the continuous availability of biomass would be a confront. Consequently, coal seems to be a promising fuel for producing methanol in India.

Properties of Methanol (Comparative Chart)

Methanol is a colorless poisonous liquid, entirely miscible with water and organic solvents and is very hygroscopic. It has high-octane number, clean-burning fuel so that it is significant alternate for gasoline in automotive vehicles.

Table 7: Properties of Methanol and Gasoline (Comparative Chart) (Kamboj & Kairimi 2017) (Liu et al. 2007)

Sr.No.	Characteristics	Methanol	Gasoline
1	Chemical formula	CH_3OH	C8H18
2	Molecular wt. (kg/kmol)	32	100-105
3	Boiling point(ºC) at atmospheric pr.	64.5 C	30-225
4	Density at 20 (ºC) (kg/m³)	796.6	700-780
5	Chemically correct air fuel ratio	6.4:1	14.7:1
6	Cetane number	55-60	0-10
7	Octane number	111	80-90
8	Calorific value (MJ/Kg)	23.7	43.6
9	Flash point (ºC)	11	43
10	Lower heating value	20	42
11	Oxygen content (wt %)	50	0
12	Auto Ignition temp. ºC	464	390-420
13	Sp. Gravity	0.8	0.7-0.8
14	Latent heat of vapor(Kj/Kg)	1103	305
15	Freezing temp ºC	-97.7	-57

Based on the comparison of the properties of both the fuels a comparative statement is made and is given in the Table 8.

Table 8: Comparison of Methanol & Gasoline as a fuel.

Sr.No.	Methanol as S I engine fuel advantages	Methanol as S I engine fuel shortcomings
1	High stoichiometric fuel air ratio	Longer ignition delay.
2	High oxygen content, high hydrogen to carbon ratio and low sulphur content	More corrosive.
3	High latent heat of vaporization.	Lower energy content.
4	Reduced soot and smoke.	Lower flash point.
5	Higher cooling, hence less compression work.	Poor combustion characteristics.

From Table 8, it can be said that methanol can replace gasoline in small amount such that its positive properties can be well exploited and negative effects can lessened. It is possible by operating SI engines with methanol and Gasoline blends. A good range of research has been carried out so far for to develop possible ways to use methanol in SI engines. A brief review of some important research outcomes is discussed below in the literature Review.

II. LITERATURE REVIEW:

The literature review has been divided in four parts

a. Effect on the performance of single cylinder engine by using methanol blends.

Kamboj & karimi (2014) performed experiment on single cylinder 4-stroke spark ignition Engine (SI) with methanol gasoline blend and found indicated power (I.P), brake power (B.P), indicated mean effective pressure (I.M.E.P), torque, exhaust temperature, and thermal efficiency (η) increases when engine speed rises (1100 rpm to 1800 rpm) with uniform load of 8 Kg for 5% methanol-gasoline blend. During the same period (Ahmed 2013) conducted same nature of experiments and concluded that with increasing the blending percentage of methanol brake power and brake thermal efficiency increases due to higher cylinder temperatures. They further informed that the fuel consumption of the blend is lower than of the pure gasoline for 10% methanol blend. (Iliev 2014) conducted series of experiment by using various methanol-gasoline blends and observed that brake specific fuel consumption (B.S.F.C), torque & brake power improved with increased fraction of methanol in gasoline. (Balki, Cenk & Canakci 2014) conducted experimental study on a single-cylinder engine operating on methanol fuel with different compression ratios and different engine speed. Their results showed that the use of alcohol fuels increased the engine torque, brake specific fuel

consumption (BSFC), thermal efficiency and combustion efficiency. (Liu et al. 2007) in their research claimed that with increasing fraction of methanol in the fuel under wide open throttle (W.O.T) conditions, the engine power and torque decreased. However, engine power and torque can be improved, with advanced spark ignition timing. Their study further claimed that in almost all operating conditions thermal efficiency is enhanced. (Zaid et al. 2004) carried out experiments with methanol gasoline blends on SI engines, at W.O.T and different speed conditions, (range of 900 to 2400 rpm). Their findings are that maximum power output and minimum B.S.F.C takes place at Methanol 15% blend. Octane number of the blend increased with the addition of Methanol to gasoline which makes engines operate at higher compression ratio. (Kowalewicz 1993) examined the use of methanol in spark ignition engine and concluded that a neat methanol fuelled engine has 30% more efficiency than a gasoline engine, not only due to high compression ratio but also due to methanol's higher latent heat of vaporization which lowers the temperature of air in the engine, which further increases the density and permitting more air in during suction stroke. This results in a leaner fuel mixture. (Vino et al. 2013) in their study observed that as the percentage of alcohol increases power output decreases. By making engine modification such as increasing the engine compression ratio and advancing the ignition timing, approximately 12.5% increase in the power output has been attained. (Elfasakhany 2015) performed tests on SI Engine fuelled with methanol gasoline blends ethanol gasoline blend and ethanol methanol gasoline blends (3-10%) by volume and evaluated the process of combustion. (Shenghua et al. 2007) carried out their research on S.I engine fuelled with blends of methanol. They concluded that the brake thermal efficiency (B.T.E) improved while engine power and torque decreased. The maximum pressure is higher for 20 % Methanol blends as compared to pure gasoline under 50% WOT & same engine speed. (Kamboj & Kairimi 2014) performed an experiment on single cylinder 4S Spark ignition engine fuelled with blends of M5 & M20 with Gasoline as base fuel and blends of E5 &E20 with Gasoline as base fuel at varying engine speed (1200rpm to 1750 rpm) . It has been observed that volumetric efficiency is highest for M20 fuel and minimum for iso-octane. BSFC is maximum for M-20 and minimum for M-5. The value of η was maximum at 1400 rpm for M-5 fuel blend and minimum for M20 fuel that in turn leads to high emission temperature for M-5 fuel. The best results were obtained with Methanol 5 blend fuel because of high efficiency and BSFC. (Kumar & Sagar 2014) performed a test by using blends of

methanol gasoline blends of 5%, 10%, 15% methanol by volume and evaluate performance. It has been found that brake specific fuel consumption and brake thermal efficiency of M5 blends is same as that of pure Gasoline. Lowest thermal efficiency and highest brake specific fuel consumption occurs at M15 blends almost at all loads and speeds. Fuel miscibility problem occurs at about M10 to M15 blends for that engine modification such as enlargement of fuel nozzle was recommended.

(Varshney & Mishra 2016) carried out experimental study on SI Engine with gasoline methanol blend and found M15 blend of methanol provide better engine performance. Due to high octane value of methanol, high heat of vaporization, methanol addition to gasoline improves the SI engine cold start. (Iliev 2015) developed one dimensional model of a 4 stroke spark ignition engine for predicting the effect of different blends of ethanol, methanol and gasoline (by volume) on engine performances and fuel consumption on different engine operating conditions. Performance analysis is done with the help of simulation tool of AVL Boost. He found that B.P decreased and the BSFC increased compared to pure gasoline (Zhen 2018) on the basis of analysis described that methanol as an best alternative of fossils fuels which meet various emission regulation and keep the environment clean, compared with gasoline, methanol has better fuel conversion efficiencies due to larger heat of vaporization and much better resistance to knock. (Reed & Lerner 1973) explained the properties of methanol where in that they described it as fluid with no color, smell & miscible with water. It freezes at -97.8 ºC, boils at 64.6 ºC having auto-ignition temperature 467 ºC, which is high compared with 222 ºC for gasoline. The octane number of methanol is very high i.e. 106 as compared to gasoline (90 to 100). Properties of Methanol make it suitable as fuel along with other fuel. Small quantity of methanol in gasoline acts an additive which can remove problem of both energy and air pollution**.** (Rakesh & Simhadri 2016) worked on 4stroke single cylinder (150cc) spark ignition engine of two wheeler by using methanol gasoline blends and ethanol gasoline blends (20%,40%,60%,80% and 100%).Analysis is carried out with inlet air preheated or without preheating the inlet air. He found that 20% of methanol with petrol (before preheating & after preheating) has given better results than that of the Gasoline and other blended propositions. Brake specific fuel consumption increases by 2.7% and brake thermal efficiency decreases by 0.0105. (Ghazal 2017) analyzed the effect of engine speed and compression ratio on S.I engine which was working on methanol gasoline blends. The results demonstrate that

when engine speed increased the engine output power and fuel consumption increases and brake mean effective pressure (BMEP), torque and thermal efficiency decreases. (Pankhaniya, Chauhan & Ranpara 2011) carried an experiment on SI Engine using methanol gasoline blends up till M20 at engine speed 2000 rpm under variable load condition. Their results indicated that brake power is 10% higher than pure gasoline at full load conditions. For M5 blend the brake specific fuel consumption obtained was 0.1615 kg/KW-hr which is lower about 8% and brake thermal efficiency increased by 5% than pure petrol at constant speed condition. (Ozsezen & Canakci 2011) performed test on a vehicle by using an eddy current chassis dynamometer and compared the results with pure gasoline. Their findings are at M-5 minimum CO_2 emission were present at all vehicle speeds. The alcohol gasoline blends at all vehicle speeds provided slightly higher combustion efficiency as compared to 100 % gasoline. The combustion efficiency and the equivalence ratio rise with the rise of vehicle speed. (Gravalos et al. 2011) expressed the performance characteristics of blended fuels on non road SI engine. They found that ethanol gasoline blended fuels increase the brake power and brake torque, and decreases the brake specific fuel consumption while methanol gasoline blended fuels show lesser brake power and brake torque and higher brake specific fuel consumption than gasoline. (Yamamoto 1972) concluded from his research that the calorific value of methanol is less than that of gasoline so that its blends have less energy. Methanol has a high octane number, which increases with the increase of methanol concentration. This effect reveals the elimination of knocking. (Qi et al. 2005) found that the critical phase separation temperature (CPST) of methanol-gasoline blend increased with increasing water content in the blend and it can be decreased by adding ethanol as co-solvent. In his experiment he utilized M10 (90 vol % gasoline + 8.5 vol % methanol +1.5 vol % ethanol) and M25 (75 vol % gasoline + 19 vol % methanol + 6 vol % ethanol) to investigate the performance, Specific fuel Consumption (SFC) and the tail pipe emissions. His results indicated that the SFC of M-10 was almost equivalent to that of gasoline, but for M-25 SFC was higher for all engine speeds when operated at full load. (Yanju et al. 2008) performed an experiment on a three-cylinder port fuel injection engine to investigate the performance characteristics using methanol gasoline blends at the volumetric rates of 10%, 15%, 20%, 25% and 30% to gasoline. They observed that the engine power and torque declined with the increase fraction of methanol in the fuel blends without any retrofit of the engine. (Shayan et al. 2011) carried out an experiment on four cylinder four stroke

multipoint injection system of SI Engine with different blends (M-5, M-7.5, M-10, M-12.5, M-15) and found torque, BP, BTE, volumetric efficiency, equivalence air-fuel (A/F) ratio, and BSFC improved with the usage of methanol under WOT condition and different engine speed varying from 1500 to 5000 rpm.(Eyidogan et al. 2010) investigated the effects of methanol–gasoline (M5, M10) fuel blends on the performance and combustion characteristics of a vehicle having a four-cylinder, four-stroke, multi-point injection spark ignition engine. The tests were conducted with chassis dynamometer wherein the vehicle was running at two different speeds (80 km/h and 100 km/h). They concluded that the BSFC increased while gas pressure inside the cylinder begins to rise later than gasoline fuel. It was observed that mostly in the all test conditions, the lowest peak heat release rate was obtained from the gasoline fuel.(Hu et al. 2007) observed that at the commencement of combustion advanced and rapid burning, phase became shorter with the addition of methanol to gasoline. The maximum cylinder gas pressure of the methanol gasoline fuel blends became higher as compared to pure gasoline under the similar engine speed and throttle opening. (Mallikarjun & Mamillah 2009) conducted experiments and observed that there is an increase in brake thermal efficiency, indicated thermal efficiency and reduction in knocking by incorporating some modifications in engine. (Basavaraju et al. 2013) conducted experiment on 350cc 4 stroke single cylinder spark ignition engine with compression ratio 7.5/1 with methanol gasoline blends. The observations have been taken under no load and at different loads keeping the speed of hydraulic dynamometer at 250 rpm throughout the test. The engine produced a maximum power of 7.7 KW at 1330 rpm which resulted in uncontrollable vibrations.

b. Emissions of single cylinder engine by using methanol blends.

(Goyal et al. 2015) performed experiment on engine with methanol-gasoline blends (M5 and M10) and observed that the vehicular emissions CO_2, CO, HC and NOx decreased at all wheel powers at constant speed of 90 km/h. (Ahmed 2013) carried out an experiment on 4 stroke SI engine by using gasoline methanol blends at different loads and found that with increasing the blending percentage of methanol there is reduction in emitted concentration of carbon oxides and HC. (Taksande & Kongre 2013) studied SI Engine using various alcohol gasoline blends at variable load and concluded that the emissions CO, CO_2 , HC gets reduced. All tests were conducted on a single-cylinder Waukesha Cooperative Fuel Research (CFR) engine operating at steady state conditions and stoichiometric air-to-fuel ratio.(Iliev 2014) observed that when

blends fraction increased, the CO and HC emission decreases and increase in NOx emission when fuel blends percentage rises up to M30. (Balki et al. 2014) carried out an experimental study and concluded that HC, CO and NOx emissions decreased compared to conventional gasoline engine when blends were used. (Farkade & Pathre 2012) investigate the impact of methanol, ethanol and butanol blends with gasoline on SI engine and found that due to presence of more oxygen content in alcohol it gives more desirable combustion which results in low emission of CO, HC and higher emission of CO_2 as a result of complete combustion. Higher temperature is also favorable for NO emission resulting higher emissions of it. (Kowalewicz 1993) examined the use of methanol in spark ignition engine and found that a neat methanol fuelled engine has 30% more efficiency than a gasoline engine, not only due to high compression ratio but also due to methanol's higher latent heat of vaporization which decreases the temperature of the air in the engine to a greater extent, which further increased the density and permitted more air in cylinder. This results in a leaner fuel mixture, possibly reducing the emission of CO due to more absolute combustion. (Elfasakhany 2015) concluded that methanol gasoline blends provide lowest emission of carbon monoxide and unburnt hydrocarbon among all blends. (Varshney & Mishra 2016) found that M15 blend of methanol provide better engine performance due to high octane value of methanol, high heat of vaporization. Also methanol addition to gasoline improves the SI engine cold start and lower CO and HC emissions significantly. (Iliev 2015) from its one dimensional model predicted the effect of different blends of ethanol, methanol and gasoline on emission characteristics at different engine operating conditions. When fuel blends percentage increases up to 30% with M-30 & E-30 the CO and HC concentration decreases and there is a significant increase NOx emission. (Reed & Lerner, 1973) analyzed the auto-ignition temperature of methanol as 468 ºC, which is high compared with 222 ºC for gasoline. The octane number of methanol is very high i.e. 106 as compared to gasoline (90 to 100) So that it can be used as an additive or substitute that can solve both energy and emission problems. (Ghazal 2017) analyzed the effect of engine speed and compression ratio. He found at increased engine speed carbon monoxide (CO) emission also increases. Besides, when compression ratio increased the CO emission decreased. (Kumar & Sagar 2014) carried experiment on two wheeler to check the tail pipe emission and compared the emission before and after installing catalytic converter in a motor bike and found the reduction in emission of CO and HC by 51.21% and 50% respectively.

(Bata & Roan 2009) carried out tests at different conditions of equivalence ratio and spark timing. They found the presence of methanol in fuel blends appreciably reduced the concentration of carbon monoxide in the exhaust emissions (up to 40–50 percent). Hydrocarbon emissions were also decreased by increasing the Methanol content. The 10 percent Methanol-gasoline blends were found to produce about 50 percent more aldehyde emissions than pure gasoline. (Qi et al. 2005) found that the HC emission of M-25 was greater and the NO_x emissions were lower. For M-10 for all engine loads under low and moderate loads, the CO emission of gasoline was on higher side than that of methanol-gasoline blends. (Gravalos et al. 2011) analyzed the emission characteristics of alcohols addition in gasoline in SI engine. The use of blends, containing high ratios of alcohols, at 2000 rpm engine speed with full throttle valve opening, have considerable effect on the reduction in exhaust emissions. (Yamamoto 1972) concluded that since methanol has a more octane number, which rises with the methanol % thus reduces knocking. Thus changing anti-knock additives in gasoline with a small addition of methanol's in a blend, helps to reduce pollution. (Yanju et al. 2008) performed an experiment on a 3-cylinder port fuel injection engine to investigate the emission characteristics using methanol gasoline blends at the volumetric rates of 10%, 15%, 20%, 25% and 30% to gasoline. They observed that 30% reduction in HC emission and 25% reduction in CO emission when the engine was fuelled with M30 (30% methanol + 70% gasoline. (Shayan et al. 2011) carried out an experiment with different blends and concluded that exhaust emissions (CO, CO_2, HC, NOx) improved with the usage of methanol with WOT and different engine rpm varying from 1400 to 4900 rpm..

c. Effect of the Methanol and its blends on the engine hard ware.

Methanol on combustion produces more vapor and forms acidic products that cause wearing of cylinder, valves & valve seats because of more hydrocarbon burning. Additives can be added to the fuel in order to nullify the effect of acids. Methanol has both soluble and insoluble contaminants (Burton et al. 2000). It forms oxide films, causes several metal pitting corrosion. Soluble contaminants, like aluminum hydroxide which is a product of corrosion, clog the fuel system over a span of time. Due to its hygroscopic nature it has tendency to absorb water vapour and causes phase separation of methanol and gasoline blends that is why containers of methanol fuels must be kept tightly sealed (Brinkman et al. 2006)

d. Technologies available for two wheelers for making it BS Compliance.

The major change in a two wheeler for conversion to BS IV norms (Vashist et al. 2017)

a. Addition of carbon canisters to control evaporative emissions.
b. Lower limits of emissions, would be taken care by optimization of the burning process inside the cylinder and increasing the volume and surface area of catalyst used in the catalytic convertor.

The changes in a two wheeler for conversion to BS VI norms skipping BS V norm applicable from April 2020 are (Vashist et al. 2017)

a. The two wheelers will also have to discard Carburetor system Electronic Fuel Injection (EFI) system will take its place.
b. Particulate Matter reduction is also considered in BS-VI norms.
c. PM and NOx emissions from the engines will get further reduced once sulphur content in BS-VI fuels is limited to only 10 parts per million (ppm).

The cost impact of Electronic Fuel Injection system (EFI) systems on two-wheelers with existing levels of localization is expected to higher by 10 to 20 per cent, which is around INR 6000-9000 with carburetor equipped system at present. The costs however, are expected to come down subsequently as parts in the EFI system get localized and the ancillaries pass on benefits to the Original Equipment Manufacturers (OEMs).

From the literature survey it can be concluded that more tests on the performance of blends has to performed for getting a complete knowhow about the emissions since very less work in this area has been conducted. Also the effects of the blends on the engine hardware material behavior have not been deeply studied. Tail pipe emission reduction is also one area where more emphasis is required for making this blended fuel system compliance with the BS VI norms with this in mind the study will be conducted with objectives given at section 3.

III. OBJECTIVES OF STUDY

As per NITI Aayog report (Saraswat & Bansal 2006) the Government of India has decided to spend 4000 to 5000 crore for the production of methanol as an alternative fuel so that the annual oil import bill may be reduced by $100 billion till 2030. The two wheelers that are 10-15 years old / not following BS-IV norms contribute 90% of this segment. They are the major contributors of emissions in the NCR / Metros. Methanol being a renewable fuel having good

combustion properties and can be easily blended with gasoline. A very little information about the emission by the usage of methanol gasoline blends on two wheeler which are more than 10 years old and effect on hard ware of these blends is available in the literature. Also many developments for technology up-gradation in the area of emission reduction are regularly taking place to make two wheelers compatible with BS VI Norms. This study will be one foot forward for reduced emission from two wheelers by making use of Methanol gasoline blend. With this in the background the study will have the following objectives:

1. To study and analyze the performance parameters of blends with the help of mathematical tools.(Paper already Published)
2. To review the existing methods and techniques to control vehicular tail pipe emissions applicable for two wheeler industry. (Patent to be filed)
3. To study the available technology for shifting from BS IV to BS VI Norms for two wheelers.
4. To study the major challenges those are faced by auto and oil sector for bringing BS VI Norms for two wheeler industry. (Paper already Published)
5. To study the effect of methanol gasoline blends on engine hard ware.
6. To develop methanol blends and analyze its properties.
7. To analyze behavior of emission parameters of single cylinder gasoline engine working on methanol gasoline blends.
8. To device a retro fitment system for reduction of emission of single cylinder gasoline engine working on methanol gasoline blends.

IV. METHODOLOGY

a. Selection of single cylinder 4 stroke gasoline operated two wheeler.
b. Preparation of methanol gasoline blends. (5%, 10%, 15% by volume)
c. Identifying the properties of the blends and comparing it with gasoline.
d. Use of these blends (5%, 10%, and 15% by volume) in the selected engine and measuring emission data at various operating conditions.
e. Relationship between various variables will be established.
f. Mathematical permutation model for the relationship between various emission factors will be hypothesized.

g. Modification in the tail pipe emission for reduced emission will be made.

Sample selection:

Two wheeler (with major market share in the Indian market) having single cylinder gasoline engine will be selected for the study.

Data collection:

a. Emission data for different load parameters will be collected for pure gasoline and for different blends ratios as per the Table 9.

b. Tail pipes emission data will be collected with and without developed retrofit system as per Table 10.

c. Analysis presented for the effect on the engine hardware with the use of Methanol Blends as per the Table 11.

Table 9: Emission data for engine working on blends under variable load

Emission data for engine working on blends under variable load				
Emission	Gasoline	Metanol 5% Blend	Metanol 10% Blend	Metanol 15% Blend
HC				
NO_x				
CO				
CO_2				
PM				

Table 10 : Emission data for engine working on blends under variable load with and without retrofit

Emission data for engine working on blends under variable load with and without retrofit								
Emission%	Gasoline (100%)		M5		M10		M15	
	With Retrofit	Without Retrofit	With Retrofit	Without Retrofit	With Retrofit	With Retrofit	With Retrofit	Without Retrofit
HC								
NOx								
PM								
CO								
CO_2								

Table 11. Effect on Engine hardware with fuel type

Effect on Engine hardware				
	Effect			
Fuel Type	Part 1	Part 2	Part 3	Part 4
Gasoline				
Metanol 5% Blend				
Metanol 10% Blend				
Metanol 15% Blend				

Data Analysis:

Based on emission data for different loads, statistical analysis shall be done to ascertain usage of methanol in the existing system.

V. PROPOSED OUTCOME

- The analysis so developed shall be useful in our ability to compare and then further reduce emission level by using methanol gasoline blends. A know how of the impact of different emission factors and ascertain the sensitivity of vehicle emission to each of these factors will also be the outcome of the research.
- This comparison shall explain how different factors influence vehicle emission and which factors are more influential.
- Effect on the hardware of the methanol blends on the system and how the same can be reduced or minimized will be explained with proper reasoning.
- The detailed statistical analysis of emission values with respect to different percentages of methanol blends shall provide evidence as to how the prepared blends are capable of compliance BS norms.
- This study will help in planning for emission reduction strategies by taking renewable fuel methanol as one of the alternatives.

Based on this research papers in international journals will be published.

A retro-fitment system shall be dev ised to reduce emission of two wheelers to make the vehicle compliant under proposed BS emission norms for which patent will be applied.

VI .TIME LINE FOR Ph.D RESEARCH

Time line for major five activities is given below in the form of chart.

Sr. No.	Activity	2017												2018												2019											
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
1	Literature Survey																																				
2	Data Collection																																				
3	Select of Analytical Techniques/Methods																																				
4	Data Analysis with inferences and suggestion																																				
5	Thesis Preparation and submission																																				

REFERENCES:

1. Ahmed, S.S., 2013, 'Effect of Methanol-Gasoline Blends on S.I. Engines Performance and Pollution', International Journal of Mechanical & Mechatronics Engineering, Vol: 13 No: 05, pp. 50-53.

2. Balki, M.K., Cenk, S. & Canakci, M., 2014, 'The Effect of different alcohol fuels on the performance, emission and combustion characteristics of a gasoline engine' Fuel: 115 pp. 901–906.
3. Basavaraju, A. N., Gonsalvis, J. & Yogesha, B., 2013, 'Performance study of methanol blended petrol in SI Engine', International journal of engineering science Invention, ISSN: 2319-6734.
4. Bata, R.M. & Roan, V.P., 2009, 'Effects of ethanol & methanol in alcohol-gasoline blends on exhaust emission', The American society of mechanical Engineers, Gas turbine power, 111(3), 432-438.
5. Berman, E. & Linda, T.M., 2001, 'Environmental Regulation and Productivity: Evidence from oil Refineries', The Review of economics and statistics.83 (3):498-510.
6. Brinkman, N., Halsall, R., Jorgensen, S.W., & Kirwan, J.E., 2006, 'The Development of Improved Fuel Specifications for Methanol (M85) and Ethanol (Ed85)', SAE Technical Paper 940764.
7. BSES, 2017,wikipediahttps://en.wikipedia.org/wiki/Bharat_Stage_emission_standards.
8. Burton, G., Holman, J. & Lazonby, J., 2000, 'Salters Advanced Chemistry: Chemical Storylines', (2nd Ed.). Heinemann. ISBN 0-435-63119-5.
9. Elfasakhany, A., 2015, 'Investigation on the effects of ethanol-methanol-gasoline blends in a spark ignition engine: performance and emission analysis', International journal of Engineering science and Technology, 18(2015)713-719.
10. Eyidogan, M., Ozsezen, A. N.,Canakci, M. & Turkcan, A.,2010, ' Impact of alcohol–gasoline fuel blends on the performance and combustion characteristics of an SI engine', Fuel , Volume 89, Issue 10 , 2713–2720 .
11. Farkade, H.S. & Pathre, A.P. ,2012, ' Experimental investigation of methanol, ethanol and butanol blends with gasoline on SI Engine', International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, Volume 2, Issue 4.
12. Ghazal, O., 2017, 'Numerical analysis of S I Engine operating on methanol fuel', International journal of applied engineering research, ISSN 0973-4562 Vol.12, No.6.pp 861-865.

13. Goyal,P., Sharma,S.K. & Tyagi, R.,2015, ‘ Evaluation of methanol Gasoline Fuel Blends on exhaust Emission of Single Cylinder Spark Ignition Engine’, Iranica Journal of Energy and Environment, 6(3), (161- 166).
14. Gravalos, I., Moshou, D., Gialamas, T. & Tsiropoulos, Z., 2011, ‘Performance and emission characteristics of spark ignition engine fuelled with ethanol and methanol gasoline blended fuels’, Environmental sciences, “Alternate fuel” book, ISSN 978-953-307-372-9.
15. Hu, T.,Wei, Y., Liu, S.,& Zhou, L.,2007, ‘ Improvement of spark-ignition (SI) engine combustion and emission during cold start, fueled with methanol/gasoline blends’, Energy Fuel, Vol.21, pp.171–175.
16. Iliev, P.S., 2014, ‘ Theoretical study of engine performance working on methanol gasoline blends’, Proceeding of the world congress on engineering, Vol. 2, WCE, July 2-4, London, U.K .
17. Iliev, S., 2015, ‘A comparison of ethanol and methanol blending with gasoline using a 1-D Engine model’, Procedia Engineering, 1013-1022.
18. Kamboj, S. K. & Karimi, M.N., 2014, ‘A Study of Spark Ignition Engine Fueled with Methanol and Ethanol Fuel Blends with Iso-Octane’, International Journal of Thermal & Environmental Engineering, Volume 8, No. 1 (25-31).
19. Kamboj,S.K.& Karimi, M.N.,2014, ‘ A comparison of performance parameters with use of ethanol and methanol fuels blends and engine speed of S I Engine’, Thermal Energy and power engineering, Vol. 3,Issue1, pp-198-205.
20. Kowalewicz, A., 1993, ‘Methanol as a fuel for spark ignition engines, a review and analysis’, Proc. Institution of Mechanical Engineers, 207 (D1), pp. 43- 51.
21. Kumar, H. & Sagar, J. K., 2014, ‘Performance evaluation of a four stroke engine at gasoline and at varying gasoline –methanol blends. International conference of advance research and innovation, ISBH 978-93-9156-328.
22. Liu, S., Eddy, R., Clemente, C., Hu, T., & Wei, Y., 2007, ‘Study of spark ignition engine fuelled with methanol/gasoline fuel blends’, Applied thermal Engineering, 2719041910.
23. Mallikarjun,M.V. & Mamilla, V.R., 2009, ‘ Experimental study of exhaust emission and performance analysis of multicylinder S I Engine when methanol used as additive’,

International journal of electronic engineering research, ISSN 0975-6450 Vol.1 No. 3 pp.201-212

24. Malvarado, 2016, Methanol,HIS.essentialchemicalindustry.org/chemicals/methanol.html
25. Ozsezen, A.N. & Canakci, M., 2011, 'Performance & combustion characteristics of alcohol-gasoline blends at wide open throttle', Energy, 36(2011)2747-2752.
26. Pankhaniya, A.M., Chauhan, B.B. & Ranpara, C.S., 2011, 'Study of performance exhaust analysis of petrol engine using methanol gasoline blends', International conference on current trends in technology, N Ui CONE-2011.
27. PPAC, 2018, 'Petroleum Planning & analysis cell (Ministry of petroleum and natural gas, Government of India)',http://www.ppac.org.in/Write Read Data/ Reports /20180226051841163990O Monthly Report.pdf.
28. Qi, D.H., Liu, Q., Zhang, H. & Bian, Y.Z., 2005, 'Properties, performance and emissions of methanol-gasoline blends in a spark ignition engine', Proceeding of the institution of mechanical engineers part D, Journal of automobile engineering, Vol. 219 Issue 3.
29. Quora, 2015, 'Ministry of oil and Natural gas, BP Statistical Review 2015', https://www.quora.com/How-much-petrol-does-India-consume-daily-on-average .
30. Rakesh, A. & Simhadri, K., 2016, ' Experimental investigation on performance characteristics of four stroke single cylinder petrol engine using a preheating set up and fuel blends', International Journal Chem.Sci.14 (4) 2198-2210 ISSN 0972-768X.
31. Reed, T.B. & Lerner, R.M., 1973, 'Methanol: A versatile fuel for immediate use', Science 18212991304.
32. Saraswat, V.K. & Bansal, R., 2006, 'India's Leapfrog to Methanol Economy. NITI Aayog national institution for transforming India', http://niti.gov.in/writereaddata/files/document_publication/Article%20on%20Methanol%20Economy_Website.pdf.
33. Sayin, C., 2010, 'Engine performance and exhaust gas emissions of methanol and ethanol diesel blends', Fuel, 89:3410-3415.
34. Shayan,S.B.,Seyedpour,S.M.,Ommi,F.,Moosavy,S.H.&Alizadeh,M.,2011, ' Impact of methanol-gasoline fuel blends on the performance and exhaust emissions of a SI Engine', International journal of automotive engineering, Vol.1, Number 3, pp.219-227.

35. Shenghua, L., Clemente, C., Tiegang, H. & Yanjv, W., 2007, 'Study of spark ignition engine fueled with methanol/ gasoline fuel blends', Appl. Thermal Eng, 27(11-12), 1904-1910.
36. SIAM, 2017, (Society of Indian Automobile Manufactures) Report available at http://www.siamindia.com/statistics.aspx?mpgid=8&pgidtrail=9.
37. Taksande, P.A. & Kongre, S.C., 2013, 'Performance Analysis of higher alcohol / gasoline blends as a fuel in 4-stroke SI engine', Journal of Mechanical and Civil Engineering, (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X, Volume 9, Issue 6.pp 15-16.
38. Tewari, P.C. & Negi, A.S., 2015, 'Experimental investigation of S I Engine on Gasoline and ethanol gasoline blend for engine performance characteristics', International journal of engineering research & technology, ISSN: 2278-0181, Vol.4, Issue 07.
39. Varshney, N. & Mishra, D., 2016, ' Study of performance, exhaust analysis and future scope of petrol engine using methanol blends', International research journal of engineering and technology , Vol: 03 Issue: 11.
40. Vashist, D., Kumar, N. & Bindra, M., 2017, ' Technical challenges in shifting from BS-IV to BS- VI Automotive Emissions Norms by 2020 in India: A Review', Achieves of current Research international, 8(1: XX-XX, Article no. ACRI.33781 ISSN: 2454-7077)
41. Vino, J.A.V., Solomon, R. & Sreenath, S., 2013, 'Performance analysis of spark ignition engine fuelled with methanol/petrol fuel blends', Indian Journal of science and Technology, Vol-6, 4579-4582.
42. Yamamoto, T., 1972, 'Environment pollution and systematization of chemical technique- Use of methanol as fuel', Chemical economy and engineering Review, 52-57.
43. Yanju,W., Shenghua, L., Hongsong, L., Rui, Y., JIE, L. & Ying, W., 2008, ' Effects of Methanol/Gasoline Blends on a Spark Ignition Engine Performance and Emissions', Energy & Fuels, 22, 1254–1259.
44. Zaid, M. A., Badran,O. & Yamin, J., 2004, ' Effect of methanol addition to gasoline on the performance of Spark ignition engines', Energy & Fuels, 18, pp (312-315).
45. Zhen, X., 2018, 'Methanol as an internal combustion on engine fuel', Science and engineering, pp 3313-337.https://doi.org/10.1016/B978-0-444-63903-5.00011-X.